

WRITTEN FOR THE SUNDAY REPUBLIC The material prosperity of the last cen-tury is due to the co-operation of three classes of men; the man of science, who lives only for truth and the discovery of nature's laws; the inventor, eager to apply these discoveries to money-making machines and processes, and the engineer, trained in mathematical investigation and in knowledge of the physical conditions which govern his profession, which is the mechanical application of the laws of na-

Engineering is sometimes divided into civil, military and naval engineering. The term civil engineering, which will be here described, is often used by writers as covernig structural engineering only, but it

has a much wider meaning.

The logical classification is; statical engineering, including that of all fixed bodies, and dynamical, covering the movement of all bodies by the development and application of power.

Statical engineering can be again subdivided into structural engineering, or that of railways, highways, bridges, foundations, tunnels, buildings, etc.; also, into hydraulic engineering, which governs the application of water to canais, river improvements, harbors, the supply of water to towns and for irrigation, disposal of sewage, etc. Dynamical engineering can be divided

into mechanical engineering, which covers the construction of all prime motors, the transmission of power, and the use of machines and machine tools: Closely allied is ejectrical engineering, the art of the trans-formation and transmission of energy for traction, lighting, telegraphy, telephoning, operating machinery and many other uses, such as its electrolytic application to ores and metals.

Then we have the combined application of statical, mechanical and electrical engineering to what is now called industrial engineering, or the production of articles useful to man. This may be divided into agricultural, mining, metallurgical and chemical engineering.

Surely this is a vast field, and can only be hastily described in the sketch which we are about to give.

This is the oldest of all. We have not been able to surpass the works of the past in grandeur or durability. The pyramids of Egypt still stand, and will stand for thou-sands of years. Roman bridges, aqueducts and sewers still perform their duties. Joseph's canal still irrigates Lower Egypt. The great wall of China, running for 1,500 over mountains and plains, contains miles over mountains and plains, contains 150,000,000 cubic yards of materials, and is the greatest of artificial works. No modern building compares in grandeur with St. Peter's, and the mediaeval cathedrals shame our puny imitations.

These mighty works were built to show the plety of the church or to gratify the pride of Kings. Time and money were of no account. All this has now been changed. Capital controls and the question of time. money and usefulness rules everything. Hence come scientific design and labor-sav-

ing machinery.

The engineer of our modern works first calculates the stresses on all their parts, and proportions them accordingly, so that there is no waste of material. Hand labor has given place to steam machinery. All parts are interchangeable, so that they can be made and fitted together in the least possible time, as is seen every day in the construction of a steel-framed office building. Our workmen receive much higher wages than in the past, while time and cost have been diminished.

Building Railways the Greatest Feat of the Century.

The greatest engineering work of the Nineteenth Century was the development of the railway system, which has changed the face of the world. Beginning in 1830 with the locomotive of George Stephenson, it has extended with such strides that, after seventy years there are 466,000 miles railways in the world, of which 190,000 niles are in the United States. Their cost is estimated at forty thousand millions of llars, of which ten thousand millions be-

ong to the United States.

The rapidity with which railways are built in the United States and Canada contrasts strongly with what has been done in other Much has been written of the energy of Russia in building 3,000 miles of Siberian railway in five or six years. In the United States an average of 6.147 miles was ted every year during ten successive years, and in 1887 there were built 12,982 The physical difficulties overcome in Siberia are no greater than have been over-

This rapid construction is due to several causes, the most potent of which has been the need of extending railways over great distances with little money. Hence they were built economically, and at first in not er gradients, sharper curves and lighter rails used. This rendered necessary a different kind of rolling stock suitable to such construction. The swiveling truck and equalizing beam enabled our engines to run safely on tracks where the rigid European engines would soon have been in the ditch.

Our cars were made longer, and by the use of longitudinal framing much stronger. A great economy came from the use of an nealed cast-iron wheels, with hardened tires, all in one piece, instead of being built up of snokes, hubs and tires in separate parts much less than European wheels. As there are some 11,000,000 car wheels in use in the inited States the resulting economy is

It was soon seen that longer cars would carry a greater proportion of paying load, and the more cars that one engine could draw in a train the less would be the cost was not until the invention by Bessemer in 1864 of a steel of quality and cost that made it available for rails that much h cars and locomotives could be used. There came a rapid increase. As soon as Besseme rails were made in this country, the cos fell from \$175 per ton to \$50, and now to \$26. Before that time a wooden car weighed sixteen tons and could carry a paying load of tweatly-five tons. The thirty-ton engine of these days could not draw on a level over thirty cars, weighing 1,230 tons

e pressed steel car of to-day weighs no more than the wooden car, but carries a paying load of fifty tons. The heaviest engines can now draw on a level 100 steel cars, weighing 6,600 tons. In the one case, the paying load of an engine was 750 tons; now

it is 5,000 tona.
Steep grades soon developed a better brake system, and these heavier trains have led to the invention of the automatic brake worked from the engine, and also automatic couplers, saving time and many lives. The of our railways has been greatly creased by the use of electric block si

The perfecting of both the railway and its olling stock has led to remarkable results. We have no accurate statistics of the of American rallways. In or's Manual estimated their total freight tonnage at \$75,000,000 and the total

average rate per ton of \$5.83. In 1899 Poor gives the total freight tonnage at \$35,789,941 tons, and the freight receipts at \$322,436,314, or an average rate per ton of the additional yearly cost to the public would have been \$4,275,000,000, or sufficient to ace the whole railway system in two and

This is an illustration only, but a very

our railways, and the consequent fall in freight rates, have been potent factors in enabling the United States to send abroad last year \$1,456,000,000 worth of exports and flood the world with our food and manufactured products.

Picturesqueness in Bridges Has Given Place to Cheapness And Ugliness.

In early days the building of a bridge was a matter of great ceremony, and it was consecrated to protect it from evil spirits. Its construction was controlled by priests, as the title of the Pope of Rome, "Pontifex Maximus," indicates.
Railways changed all this. Instead of the

picturesque stone bridge, whose long line of low arches harmonized with the landscape, there came the straight girder or high truss, ugly indeed, but quickly built, and costing much less. Bridge construction has made greater

progress in the United States than abroad. The heavy trains that we have described heavy trains that we have described called for stronger bridges. The large American rolling-stock is not used in Eng-land, and but little on the Continent of Europe, as the width of tunnels and other obstacles will not allow of it. It is said that there is an average of one bridge for every three miles of railway in the United States, making 65,000 bridges, most of which have been replaced by new and stronger ones during the last twenty years. This demand has brought into existence

many bridge-building companies, some of whom make the whole bridge, from the ore to the finished product.

Before the advent of railways, highway bridges in America were made of wood, and called trusses. Few of them existed before railways. The large rivers and estuaries were crossed in horse boats, a trip more dangerous than an Atlantic voyage now is. A few smaller rivers had wooden truss bridges. Although originally invented by Leonardo da Vinci, in the Sixteenth Cen-tury, they were reinvented by American carpenters. Some of Burr's bridges are still standing after more than one hundred years' use. This shows what wood can do when not overstrained and protected from

The coming of railways required a stronger type of bridge to carry concentrated loads, and the Howe truss, with vertical fron rods, was invented, capable of 150-foot

About 1868 iron bridges began to take the place of wooden bridges. Die-forged eye-bars and pin connections allowed of longer panels and longer spans. The first longspan bridge was a single-track railway bridge of 400-foot span over the Ohio at Cincinnatt, which was considered to be a great achievement in 1870.

The Elegentric France of the first long-which are so completely equipped with appliances for both shop drawings and construction that the old joke becomes almost true that they can make bridges and sell-

The Kinzua viaduct, 310 feet high and over half a mile long, belongs to this era. It is the type of the numerous high viaducts now so common.

About 1885 a new material was given to Mistakes mean ruln, and the fittest only

many experiments, the proper proportions of carbon, phosphorus, sulphur, and manganese were ascertained, and uniformity resulted. The open-hearth process is now gen-erally used. This new chemical metal, for such it is, is 50 per cent stronger than Iron, and can be tied in a knot when cold.

The effect of improved devices and the use of steel is shown by the weights of the 400-foot Ohio River Iron bridge, built in 1879, and a bridge at the same place, bull in 1886.

The bridge of 1870 was of iron, had panels twelve feet long, and its height was forty-five feet, and span 400 feet. The bridge of 1886 was of steel, had pan-

els thirty feet long, and its height was eighty feet. Its span was 550 feet. The weights of the two were nearly alike. The cantilever design, which is a reviva of a very ancient type, came into use. The great Forth bridge, in Scotland, 1,600-foot span, is of this style, as are the 500-foot spans at Poughkeepsie, and now a new one

is being designed to cross the St. Lawrence near Quebec, of 1,800-foot span.

This is probably near the economic limit f cantilever construction, but the suspen sion bridge can be extended much farther as it carries no dead weight of compres-

sion members. The Niagara Suspension Bridge, of \$10-foot span, built by Roebling in 1852, and the Brooklyn bridge, of 1,600 feet, built by Roeb-ling and his son, twenty years after, marked a wonderful sdvance in bridge design. Thirty years later, when a new

was wanted to cross another part 1.600 feet of the East River at New York, the lines of construction were followed, and they will be followed in the 2,700-foot span, designed to cross the North River, some tim in the Twentieth Century. The only radical advance is the use of a better steel than could be had in earlier days.

Steel-arched bridges now are scientifically iesigned. Such are the new Niagara bridge,

of 840-foot span, and the Alexandra bridge at Paris. It is curious to see how little is said about

these beautiful bridges, which the publ takes as a matter of course. If they had been built fifty years ago their engineers would have received the same praise as Robert Stephenson or Roebling, and justly so, as they would have been men of exceptional genius. When these bridges we built, in 1888, the path had been made clear by mathematical investigation and the command of a better steel, that the task

Victoria Bridge at Montreal

Marks Great Advance.

That which marks more clearly than any thing else the great advance in American bridge building, during the last forty years is the reconstruction of the famous Victoria bridge, over the St. Lawrence, above Mor treal. This bridge was designed by Rober Stephenson, and the stone piers are a monu ment to his engineering skill. For fort winters they have resisted the great field of ice borne by a rapid current. Their dimensions were so liberal that the new bride was put upon them, although four times as

The superstructure was originally made of plate-fron tubes, re-enforced by tees and an gles, similar to Stephenson's Menai Straits bridge. There are twenty-two spans of 246 feet each and a central one of 330 feet. Per-haps these tubes were the best that could be had at the time, but they had outlived the usefulness. Their interiors had becomgreatly corroded by the confined gases from he engines and the drippings from the chemicals used in cold-storage cars. Their height was insufficient for modern large cars, and the confined smoke made them s dark that the number of trains was greatly

limited. It was decided to build a new bridge of open-work construction and of open-hearth steel. This was done, and the comparison is as follows: Old bridge, sixteen feet wide, single track, live load of one ton per foot new bridge, sixty-seven feet wide, two rall-way tracks and two carriage ways, live

load, five tons per foot. tubes weighed 10,000 tens. The old from The new truss bridge weighs 22,000 tons, has loads.

The modern high office building is an in-teresting example of the evolution of a high-viaduct pler. Such a pier of the required dimensions, strengthened by more columns strong enough to carry many ficors, is the skeleton frame. Inclose the sides with brick, stone or terra-cotta, add windows and doors and elevators and it is complete. Fortunately, for the stability of these high buildings, the effect of wind pressures had been studied in this country in the designs of the Kinzau, Peccs and other high viaducts.

Effect of Wind Pressure on High Office Buildings.

All this had been thoroughly worked out and known to our engineers before the fall of the Tay bridge in Scotland. That disas-trous event led to very careful experiments on wind pressures by Sir Benjamin Baker. the very eminent engineer of the Forth Bridge. His experiments showed that a wind gauge of 300 square feet area showed a max-imum pressure of thirty-five pounds per square foot, while a small one of one and -half square feet area registered gusts of forty-one pounds per square foot.

The modern elevated railway of cities is simply a very long railway viaduct. Some idea may be gained of the life of a modern rivetted-iron structure from the experience of the Manhattan Elevated Railway of New York. These roads were built in 1873-78 to carry uniform loads of 1,600 pounds per lineal foot, except Second avenue, which was made to carry 2,000. The stresses were below 10,000 pounds per square inch.

These viaducts have carried in twenty-two years over 25,000,000 trains, weighing over 3,000,000,000 tons, at a maximum speed of twenty-five miles an hour, and are still in good order.

Bridge engineers of the present day are free from the difficulties which confronted the early designers of iron bridges. The mathematics of bridge design was under stood in 1870, but the proportioning of de tails had to be worked out individually. Every new span was a new problem. Now the engineer tells his draftsman to design a span of a given length, height and width, and to carry such a load. By the light of experience he does this at once. Connections have become standardized so that the duplication of parts can be carried to its fullest extent.

Machine tools are used to make every part of a bridge, and power rivetters to fasten them together. Great accuracy can now be had, and the sizes of parts have in-creased in a remarkable degree. We have now great bridge companies,

true that they can make bridges and sell them by the mile. All improvements of design are now public property. All that the bridge companies do is done in the fierce light of competition.

Having such powerful aids, the American over his predecessors and over his European

brethren, where the American system has not yet been adopted. The American system gives the greatest possible rapidity of erection of the bridge on its plers. A span of 518 feet, weighing 1,000 tons, was erected at Cairo on the Mississippi in six days. The parts were no assembled until they were put upon the false works. European engineers have some gether complete in the maker's yard, and

then taken anart The adoption of American work in such oridges as the Atbara in South Africa, the Goktelk viaduct in Burmah, 320 feet high, and others, was due to low cost, quick de-livery and erection, as well as excellence of material and construction.

Superiority of the American System. The St. Louis and Brooklyn Bridges.

Bridges must have foundations for their plers. Up to the middle of the Ninteenth Century engineers knew no better way of making them than by laying bare the bed of the river by a pumped-out cofferdam, or by driving piles into the saml, as Julius About the middle of the cen-French engineer conceived the first plan of a pneumatic foundation, which led to the present system of compressing air by pumping it into an inverted box, called a calsson, with air locks on top to enable men and materials to go in and out. After the soft materials were removed, and the calsson sunk by its own weight to the proper depth, it was filled with concrete. The limit of depth is that in which men can work in compressed air without injury, and this is much over 100 feet.

The foundation of the Brooklyn and St Louis bridges were put down in this man-In the construction of the Poughkeepsie bridge over the Hudson in 1837-8, it became necessary to go down 135 feet below tidelevel before hard bottom evel before hard bottom was reached. Another process was invented to take the compressed air. Timber caiss were built, having double sides, and th spaces between them filled with stone to give weight. Their tops were left open and the American single-bucket dredge was used. This bucket was lowered and lifted by a very long wire rope worked by the engine, and with it the soft material was removed. By moving this bucket to different parts of the caisson its sinking was perfectly controlled, and the calsson finally placed in its exact position, and perfectly vertical. The internal space was then filled with concrete laid under water by the same bucket, and leveled by divers

while this work was going on, the Gov. ernment of New South Wales in Australia called for both designs and tenders for a bridge over an estuary of the sea called Hawkesbury. The conditions were the same as at Poughkeepsie, except that the soft mud reached to a dept of 160 feet be-

The designs of the engineers of the Poughkeepsie bridge were accepted, and the same method of sinking open calssons this case made of iron) was carried out with perfect success. The erection of this bridge involved an-other difficult problem. The mud was too soit and deep for piles and staging, and

the cantilever system in this site would have increased the cost.

A staging was built on a large pontoon at the shore, and the span erected upon it. The whole was then towed out to the bridge site at high tide. As the tide fell, the pontoon was lowered and the steel girder was eration was completed within six hours

The other five spans were placed in the The other ave spans to the canadian Pa-erife in placing the spans of a bridge over cife in placing the spans of a bridge over is now used in replacing old spans by new cres, as it interrupts traffic for the least perible time.

The solution of the problems presented at

Hawkesbury gave the second introduction cost between \$1,300,000 and \$1,400,000, and the of American engineers to 'ridge i ing time of construction was one year, outside of America, The first was in 1786, During his experience the writer has seen when an American carpenter or shipwright

high rates of freight as those of 1867 would the rolling load of bridges increase from have checked traffic. This much can surely be said: The reduction in cost of operating with an extra allowance for concentrated bridge was of wood supported on piles. His 1,470 feet long by forty-six feet wide. This bridge was of wood supported on piles. His work gained for him such renown that he was called to Ireland and built a sim-

ilar bridge at Belfast.

Tunneling by compressed air is a horizon-tal application of compressed-air foundations. The earth is supported by an iron tube, which is added to in rings, which are pushed forward by hydraulic jacks.

A tunnel is now being made under an arm of the sea between Boston and East Boston, some 1,400 feet long and sixty-five feet below tide. The interior lining of iron tubing is not used. The tunnel is built of concrete, re-enforced by steel rods. This will effect a considerable economy. Success in modern engineering means doing a thing in the engineering means doing a thing in the most economical way consistent with safety. The St. Clair Tunnel, which carries the Grand Trunk Railway of Canada under the of Lower Egypt, Their cost, although great, outlet of Lake Huron, is a successful ex-ample of such work. Had the North River Tunnel, at New York, been designed on equally scientific principles, it would prob-ably have been finished, which now seems

problematical. The construction of rapid-transit railways in cities is another branch of engineering, covering structural, mechanical and electrical engineering. Some of these railways are elevated, and are merely railway that dutts, but the favorite type now is that of subways. There are two kinds, those nea the surface, like the district railways of London, the subways in Paris, Berlin and Boston, and that new building in New York The South London and Central London, and other London projects, are tubes sunk fifty to eighty feet below the surface and requir-ing elevators for access. These are made on a plan devised by Greathead, and consisof cast-iron tubes pushed forward by hy-draulic rams, and having the space outside of the tube filled with liquid cement pumped into place.
The construction of the Boston subway

was difficult on account of the small width of the streets, their great traffic and the necessity of underpinning the foundations of buildings. All of this was successfully done without disturbing the traffic for a single day, and reflects great credit on the engineer. Owing to the great width of New York streets, the problem is simpler in that respect, but requires skill in design and organization, to complete the work in a short time. Although many times as long as the Boston subway, it will be built in nearly the same time. The design, where in earth, may be compared to that of a steel office building twenty miles long, laid flat on one of its sides. The reduplication of parts saves time and labor, and is the key to the anticipated rapid progress. Near the surface this subway is built in open excava-

tion, and tunneling is confined to rock.

The construction of power-houses for de veloping energy from coal and from falling water requires much structural besides elec-trical and mechanical engineering ability. The Niagara power-house is intended to de velop 100,000 horse-power; that at the Saulte Ste. Marie as much; that on the St. Law-

The contrast in size of the ower-houses is interesting. The new power-house now building by the Manhattan E.evatel Rallway, in New York, develops in the small space of 200 by 4.0 feet 100,0.0 | horse-power, or as much power as that

utilized at Niagara Falls. One of the most useful materials which mouern engineers now make use of is concrete, which can be put into confined spaces and laid under water. It costs less than masonry, while as strong. Tals is the revival of the use of a material used by the Romans. The writer was once allowed to climb a ladder and look at the construction of a dome of the Pantheon, at Rome He found it a monolithic mass of concrete, and hence without thrust. It is a better piece of engineering construction than the dome of St. Peter's, built 1,5.0 years later. The dome of Columbia College Library, in

New York, is built of concrete.

Concrete is a mixture of broken stone or gravel sand and Portland cement Its virtue depends upon the uniform good quality of the cement. The use of the rotary kiln, which exposes all the contained material to a uniform and constant intense heat, has revolutionized the manufacture of Port land cement. The engineer can now depend upon its unifority of strength.

Wheels, axles, bridges and r .lls have all been strengthened to carry their increased loads; but, strange to say, the splices which hold in place the ends of the rails, and which are really short-span bridges, are now the weakest part of a railway. The angle-bar splice has but one-third of the not be increased, owing to its want of depth. Joints go down under every passing wheel, and the ends of the rails wear out long before the rest.

This is not an insignificant detail. It has cen estimated by the officers of one of the trunk lines that a splice of proper design tamping up low joints) to buy all the new rails and fastenings required in same time It would save much more than that in the wear of rolling-stock. A perfect joint would he an economic device next in value to the Bessemer steel rail. Here is a place for scientific and practical skill.

HYDRAULIC ENGINEERING.

This is one of the oldest branches of engineering, and was developed before the last century. The irrigation works of Asia. ducts, and the canals of Europe, are examples. Hydraulic works cannot be constructed in ignorance of the laws which govern the flow of water. The action of water is relentless, as ruined canals, ob-structed rivers and washed-out dams do testify. The principal additions of the Nineteenth

Hudson River at Poughkeepsie, sixty miles Century to hydraulic engineering are the collection of larger statistics of the flow away, to a height sufficient to supply the city by gravitation through an aqueduct. of water in pipes and channels, of rainfall. run-off, and available supply. It is now known that the germs of disease can be retained by ordinary sand filters, and it is now an established fact that pure drinking nd proper drainage are a sure pre ventive of typhoid and similar fevers. Ver foul water can be made potable. Experiments show that the water of the Schuyl kill River at Philadelphia, which contains 400,000 germs in the space of less than a cubic inch, was so much purified by filter ing that only sixty remained. This is discovery of sanitary science, but the apof the engineering works of the Nineteenth plication of it is through structural engineering, which designs and executes the

fliter beds with great economy.

The removal of sewage, after having been done by the Etruscans before the foun dation of Rome, became a lost art during the dirty Dark Ages, when filth and picty were deemed to be connected in some mys-

John Wesley on Cleanliness and Its Relation to Sewerage Systems.

It was reserved for good John Wesley to point out that "cleanliness is next to godilas those for water supply. Some of then have been of great size and cost. Such are the drainage works of London, Paris, Berlin, Boston, Chicago and New Orleans. A very difficult work was the drainage of the City of Mexico, which is in a valley sur-rounded by mountains, and elevated only four or five feet above a lake having no outlet. Attempts to drain the lake have been made in vain for 600 years. It has lately been accomplished by a tunnel six miles long through the mountains and a canal of over thirty miles, the whole work costing some \$20,000,000.

The drainage of Chicago by locks and canal into the Illinois River has cost some

\$35,000,000, and is well worth its cost.
Scientific research has been applied to the designing of high masonry and concrete dams, and we know now that no well-de-signed dam on a good foundation should fail. The dams now building across the Nile by order of the British Government will create the largest artificial lakes in the world. The water thus stored will be of inestimable value in irrigating the crops

will not exceed the sums spent by lavish Khedive Ismail on useless palaces, now falling to decay.

The Suez Canal is one of the greatest hy draulic works of the last century, and is a notable instance of the displacement of hand labor by the use of machinery. Is hand labor by the use of machinery. Is-mail began by impressing a large part of the peasant population of Egypt, just as Rameses had done over 3,000 years before. These unfortunate papels. These unfortunate people were set to dig in the sand with rude hoes, and carry it away in baskets on their heads. They died

by thousands for want of water and proper food. At last the French engineers per suaded the Khedive to let them introduc steam dredging machinery. A light railway was laid to supply provisions, and a small ditch dug to bring pure water. The number of men employed fell to one-fourth. Ma-chinery did the rest. But for this the canal would never have been finished. The Panama Canal now uses the best modern machinery, and the Nicaragua Canal, if built, will apply still better meth-

ods developed on the Chicago Drainage Canal, where material was handled at a less cost than has ever been done before. Russia is better supplied with internal waterways than any other country. Her rivers rise near each other, and have long been connected by canals. It is stated that she has over 60,000 miles of internal navigation, and is now preparing the construc-tion of canals to connect the Caspian with the Baltic Sea.

The Erie Canal was one of very small cost, but its influence has been surpassed by none. The "winning of the West" was hastened many years by the construction of this work in the first quarter of the century. Two horses were just able to draw a ton of goods at the speed of two miles an hour over the wretched roads of those days. When the canal was made these two horses could draw a boat carrying 150 tons four miles an hour. Mud, or, in other words, friction, is the great enemy of civilization, and canals were the first things to diminish it, and after that railways. The Erie Canal was made by engineers, but it had to make its own engineers first,

Ste. Marie as much; that on the St. Law- as there were none available in this coun-rence, at Massena, 70,000 horse-power. These try at that time. These self-taught men. are huge works, requiring tunnels, rock-cut some of them land surveyors and others chambers and masonry and concrete in lawyers, showed themselves the equals of walls and dams. They cover large extents the Englishmen. Brindley and Smeaton. when they located a water route through the wilderness, having a uniform descent from Lake Erie to the Hudson, and which would have been so built if there had been enough money.

The question now is whether to enlarge the capacity of this canal by gravity, en-larging its prism and locks, or to increase speed and move more boats in a season by electrical appliances. The last method seem more in line with those of the present day There should be a waterway from the Hudson to Laka Erie large enough for ves-sels able to navigate the lakes and the ocean. A draft of twenty-one feet can be had, at a cost estimated at \$200,000,000.

Vessels From New York to St. Louis by Way of Great Lakes.

The deepening of the Chicago Drainage anal to the Mississippi River, and the leepening of the Mississippi itself to the Guif of Mexico, is the logical sequence of the first project. The Nicaragua Canal would then form one part of a great line of navigation, by which the products of the interior of the continent could reach ither the Atlantic or Pacific Ocean. The cost would be small, compared with the resulting benefits, and some day this

navigation will be built by the Government f the United States. The deepening of the Southwest Pass of the Mississippi River from six to thirty feet by James B. Eads was a great engiseering achievement. It was the first appli-

cation of the jetty system on a large scale. This is merely confining the flow of a river and thus increasing its velocity, so that it secures a deeper channel for itself.

The improvement of harbors follows closely the increased size of ocean and lake yesels. The approach to New York harbo

mpossible to be done without the largest application of steam machinery in a sucion dredge boat. The great increase of urban population, due to steam and electric railways, has made works of water supply and drainage

necessary everywhere. Some of these are on a very grand scale. An illustration of this is the Croton Aqueduct of New York is it now is and as it will be hereafter. This work was thought by its designers to be on a scale large enough to last for all time. It is now less than sixty years old and the population of New York will soon be too large to be supplied by it. It is able to supply 250,000,000 to 300,000,000

iam and Jerome Park reservoir are finshed will be a little over \$92,000,000. It is now suggested to store water in the Adirondack Mountains, 203 miles away, by built at the outlet of ten or twelve lakes. This will equalize the flow of the Hudson River so as to give 3,000,000,000 to 4,-000,000,000 gallons daily. It is then proposed to pump 1,000,000,000 gallons daily from the

This water would be filtered at Poughkeep-sie, and we now know that all impurities can be removed. supply will be about 1,300,000,000 gallons or enough for a population of from 60 to 12,000,000 persons. By putting in more pumps, filter beds and conduits, this supply can be increased 40 per cent, or to 1,800,000,000 gallons daily. This water would fill every day a lake one mile square by ten feet deep. This is a fair example of the scale

and Twentieth centuries.

By the application of modern labor-saving machinery, the cost of this work can be so far controlled that the cost to the city of New York per 1,000,000 gallons would be no greater than that of the present Croto supply. All works of hydraulic engineers depend

on water. But what will happen if the water all dries up? India, China, Spain, Turkey and Syria have suffered from droughts, caused clearly by the destruction of their forests. The demand for paper to print books and newspapers upon, and for other purposes, is fast converting our forests into pulp. We cannot even say, "After us the deluge," for it will seldom rain in those evil days. When the rains do come, the sponge-like vegetation of the forests being gone, the streams will be torrents at one time of the year and dried up during

THOMAS C. CLARKE.

THOMAS C. CLARKE.

Thomas Curtis Clarke, consulting engineer, has designed and built more than 125 miles of iron and steel bridges, viaducts and elevated railways. He is past president of the American Society of Civil Engineers; he is a member and Telford gold medalist of the Institution of Civil Engineers of London; and he is a member of the American Philosophical Society, Philadelphia. In conjunction with his associates he designed and built the Girard Avenue Bridge of Philadelphia; Poughkeepsie Bridge; he also designed the Third Avenue Bridge and Willis Avenue Bridge, New York.

Mr. Clarke was born at Newton, Mass., in 1827, and graduated from Harvard in 1848. He is a specialist in bridge engineering, and in his more than half a century's service has been a factor in the development of the science of engineering and bridge building.

The Steam Engine's Growth Marks the Progress of the Century.

Mechanical engineering is employed in all dynamical engineering. It covers the designs of prime motors of all sorts, steam, gas and gasoline reciprocating engines; also steam and water turbines, wind-mills and

wave-motors.

It comprises all means of transmitting power, as by shafting, ropes, pneumatic pressure and compressed air, all of which seem likely to be superseded by electricity. It covers the construction of machine tools and machinery of all kinds. It enters into all the processes of structural, hydraulic, electrical and industrial engi-neering. The special improvements are: The almost universal use of rotary motion and of the reduplication of parts.

The steam engine is a machine of reciprocating, converted into rotary, motion by the crank. The progress of mechanical engineering during the Nineteenth Century is measured by the improvements of the steam engine, principally in the direction of saving fuel, by the invention of internal com-bustion or gas engines, the application of electrical transmission, and, latest, the practical development of steam turbines, by Parsons, Westinghouse, Delaval, Curtis and others. In these a jet of steam impinges upon buckets set upon the circumference of wheel. It was clearly indicated by the Italian engineer Bronca, in 1829, but ne was too early. The time was not ripe, and there were then no machine tools giving the per-fection of workmanship required. Their advantages are that their motion is

rotary and not reciprocal. They can de-velop speed of from 5,000 to 30,000 revolu-tions per minute, while the highest ever attained by a reciprocating engine is not over 1,000. Their thermodynamic losses are less, nence they consume less steam and less

It is a very interesting fact that the basic invention upon which not only steam turbines and electric dynamos, but indeed all other parts of mechanical engineering, depend is of such remote antiquity that we know nothing of its origin. This is the depend is of such remote antiquity that we know nothing of its origin. This is the wheel which Gladstone said was the great wheel which Gladstone said was the great cost and brittleness, was only used for tools and special purposes until past the middle of the last century. This has been all changed by the invention of his there is nothing in nature to suggest it. Duplication of parts has lowered the cost of all products. Clothing is one of these. The parts of ready-made garments and shoes are now cut into shape in numbers at a time, by sharp-edged templates, and then fastened together by sewing machines. Mechanical engineering is a good example of the survival of the fittest. Millions of dollars are expended on machinery, when suddenly a new discovery or invention casts them all into the scrap heap, to be replaced by those of greater earning ca-

may come from falling fashioned water wheels of the Eighteenth Century were superseded in the Nineteenth by turbines, first invented in France and since greatly perfected. These are used in the electrical transmission of water power at Niagara of 5,000-horse power and form

a very important part of the plant. The other gravity motors are windmills and wave motors. Windmills are an old invention, but have been greatly improved in the United States by the use of the self-reefing wheel. The great plains of the West are subject to sudden, violent gales of wind, and unless the wheel was automatically self-reefing it would often be destroyed. Little has been written about these wheels, but their use is very widely extended, and they perform a most useful function in industrial engineering.

Saving of Nature's Stores Is

The Problem of To-Day.

There have been vast numbers of patents taken out for wave motors. One was invented in Chill, South America, which fur-nished a constant power for four months, and was utilized in sawing planks. The action of waves is more constant on the Pacific Coast of America than elsewhere, and ome auxiliary power, such as a gasoline engine, which can be quickly started and stopped, must be provided for use during calm days. The prime cost of such a mi bine need not exceed that of a steam plant, and the cost of operating is much less than that of any fuel-burning engine. The saving coal is a very important problem. In a of coal is a very important problem. In a saving wider sense, we may say that the saving years ago only as a horse medicine), acetylene gas, celluloid, rubber goods in all their numerous varieties, high explosives, cement. up for us during the past, and which have remained almost untouched until the Nine-

Petroleum and natural gas may disappear The ores of gold, silver and platinum will not last forever. Trees will grow, and iron ores seem to be practically inexhaustible. Chemistry has added a new metal in alu-minum, which replaces copper for many ourposes. One of the greatest problems of he Twentieth Century is to discover so hemical process for treating iron by which

eenth Century, is the great problem of to-

xidation will not take place. Coal, next to grain, is the most important f nature's gifts. It can be exhausted or the cost of mining it become so great that it cannot be obtained in the countries where it is most needed; water, wind and wave power may take its place to a limited ex-tent, and greater use may be made of the waste gases coming from blast or smelter furnaces, but as nearly all energy comes from coal, its use must be economized, and the greatest economy will come from pul-verizing coal and using it in the shape of a ine powder. Inventions have been made trying to deliver this powder into the fire-box as fast as made, for it is as explosive as gunpowder and as dangerous to store or handle. It this can be done, there will be a saving of coal due to perfect and smoke less combustion, as the admission of air can be entirely regulated, the same blast which throws in the powder furnishing oxygen. Some investigators have estimated that

which throws in the period of the period of twins and will be as great as 20 per cent. This means 100,000,000 tons of coal annually.

Bituminous coal will then be as smokeless as anthractic, and can be burned in locomotives. Cities will be free from the nuisance of wasted coal, which we call soot. This process will be the best kind of mechanical stoking, and will prevent the necessity of stoking, and will prevent the necessity of consing the doors of fire-boxes. The boiler-nually. 'floating hells." and the firing of large loco

motives will become easy.

Another problem of mechanical engineering is to determine whether it will be found more economical to transform the energy of

the rest, as we now see in the arid regions | saved. Electric energy can now transport power in high voltage economically between

coal mines and most large cities.

The second method has the advantage of not depending on one single source of supply, that may break down, but in having the energy stored in coal pockets near by the place of use, where it can be applied to separate units of power with no fear of failure.
It seems probable that a combination of
the two systems will produce the best results. Where power can be sent electrically from the mines for less cost than the coal can be transported, that method will be

To prevent stoppage of works, the separate motors and a store of coal, to be used in cases of emergency, will still be needed, just as has been described as necessary to

the commercial success of wave motors.

Any attempt by the writer of this article to trace the progress of electricity would be but a vain repetition, after the ad-mirable manner in which the subject has been treated in a former paper of this series by Professor Elihu Thomson. We can only once more emphasize the

fact that it is by the union of four separate classes of minds-scientific discoveries, inventors, engineers and capitalists-that this vast new industry has been created, which gives direct employment to thousands, and, as Bacon said 300 years ago, has "endowed the human race with new powers."

All the processes of metallurgy and min-

ing employ statical, hydraulic, mechanical and electrical engineering. Coal, without railways and canals, would be of little use, unless electrical engineering came to its nid. It was estimated by the late Lord Armstrong that of the 450,000,000 to 500,000,000 tons of coal annually produced in the world. one-third is used for steam production, one-third in metallurgical processes, and one-

third for domestic consumption. This last third for domestic consumption. This last item seems large. It is the most im-portant manufacturing industry in the world, as may be seen by comparing the coalless condition of the Eighteenth Century with coal-using condition of the Nine-teenth Century. Next in importance comes the production of Iron and steel. Steel, on account of its

steel by Bessemer in 1864, and open-hearth steel in the furnace of Slemens, perfected some twenty years since by Gilchrist and Thomas The United States have taken the lead in steel manufacture. In 1873 Great Britain made three times as much steel as the United States. Now the United States

makes twice as much as Great Britain, or 40 per cent of all the steel made in the world. Mr. Carnegle has explained the reason why, in epigrammatic phrase: "Three pounds of steel billets can be sold for 2

Prime motors derive their energy either from coal or other combinations of carbon, such as petroleum, or from gravity. This stimulates rail and water traffic and other industries, as he tells us one pound of steel requires two pounds of ore. one-third pounds of coal and one-third of a pound of limestone.

It is not surprising, therefore, that the States bordering on the lakes have created a traffic of 25,000,000 tons yearly through the Sault Ste. Marie Canel, while the Sucz. which supplies the wants of half the population of the world, has only 7,000,000, or less than the tonnage of the little Harlem River at New York.

Industrial Engineering Is the Child of the Nineteenth Century.

This leads us to our last topic, for which too little room has been left. Indi gineering covers statical, hydraulic, meal and electrical engineering, and adds a new branch which we may call chemical engineering. This is pre-eminently a child of the Nineteenth Century, and is the conversion of one thing into another by a knowledge of their chemical constituents,

When Dalton first applied mathematics to chemistry and made it quantitative, he gave the key which led to the discoveries of Cav-endish, Gay-Lussac, Berzelius, Liebig and endish, Gay-Lussac, Betzenus, Liebig and others. This new knowledge was not locked up, but at once given to the world and made use of. Its first application on a large scale was made by Napoleon in encouraging the manufacture of sugar from beets, new products were generally made from what were called "waste material." We now have the manufacture of soda, bleaching powders, aniline dyes and other

products of the distillation of coal, also coal

oil from petroleum (known fifty or sixty

artificial manures, artificial ice, beet and even beer may now be included. ice, beet sugar. Through many ages the alchemists, grop-ing in the dark and in ignorance of nature's aws, wasted their time in trying to find what they called the philosopher's stone. which they hoped would transform the baser

metals into gold. If such a thing could be found it would be a curse, as it would take away one of the most useful instruments we have-a fixed standard of value In a little over 100 years those working by the light of science have found the true philosopher's stone in modern chemistry. The value of only a part of these new prod-

ucts exceeds the nominal value of all the gold in the world. The value of our mechanical and chemical products is great, but it is surpassed by that of food products. If these did not keep pace with the increase of population, the theories of Malthus would be true, but he

never saw a modern resper.

The steam plow was invented in England some fifty years since, but the great use of agricultural machinery dates from our Civil War, when so many men were taken from war, when so many mere agriculture. It became necessary to fill their places with machinery. Without tracing the steps which have led to it, we may say that the comomn type is what is called the "binder," and is a machine called the "binder," and is a machine drawn chiefly by animals, and in some

nually. It is estimated that there are in the United States 1,500,000 of these machines, but as the harvest is earlier in the South, here are probably not over 1,000,000 in use at one time. As each machine takes the place of sixteen men, this means that 16,000,000 men are released from farming for other pursuits.

more economical to transform the energy of coal, at the mines, into electric current and send it by wire to cities and other places where it is wanted, or to carry the coal by rafl or water, as we now do, to such places, and convert it there by the steam or gas engine.

Question of the Method of

Transmission of Power.

In favor of the first method it can be said that hills of refuse coal now representing locked-up capital can be burned, and the cost of transportation and handling be